(54) Title: METHOD AND ARRANGEMENT FOR CREATING A HIGH-RESOLUTION STILL PICTURE
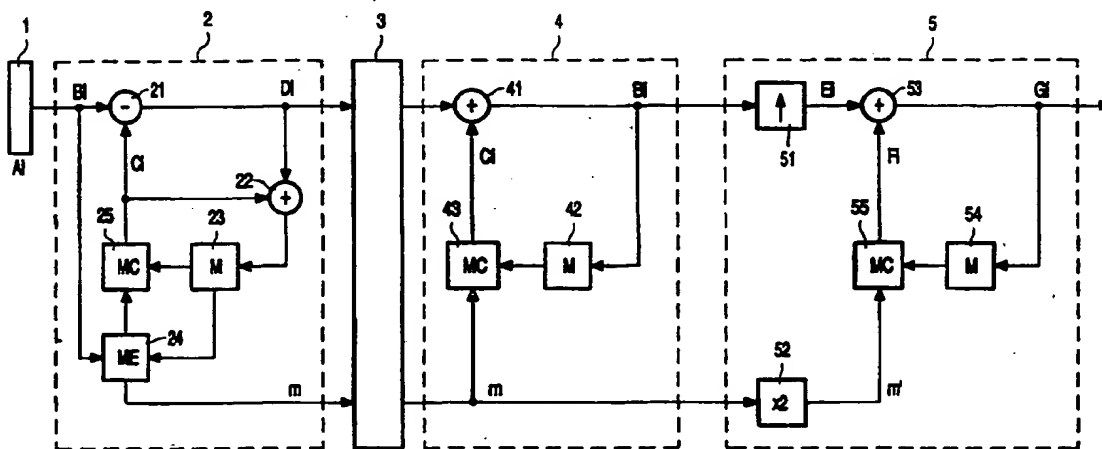
(57) Abstract

A method and arrangement is disclosed for creating a high-resolution still picture. A sequence of lower-resolution pictures is subjected to motion-compensated predictive encoding (2), preferably by an MPEG encoder producing an IPPP.. sequence of encoded pictures. The relatively small differences between successive pictures, which are due to motion of the image sensor (1) or motion in the scene, become manifest in motion vectors (m) with sub-pixel accuracy. The high-resolution picture is then created (5) from the decoded pictures and the motion vectors generated by the encoder. The invention is particularly applicable in electronic still picture cameras with a storage medium (3). The MPEG encoder (2) takes care of data compression, and the decoder (4) also allows playback of the original moving video sequence.

Method and arrangement for creating a high-resolution still picture.

FIELD OF THE INVENTION

The invention relates to a method of creating a high-resolution still picture, comprising the steps of: receiving a sequence of lower-resolution pictures; estimating motion in said sequence of lower-resolution pictures with sub-pixel accuracy; and creating the high-resolution still picture from said sequence of lower-resolution pictures and said

5   estimated motion. The invention also relates to an arrangement for creating a high-resolution still picture, for example, an electronic still-picture camera.

BACKGROUND OF THE INVENTION

A prior-art method of creating a high-resolution still picture as defined in

10   the opening paragraph is disclosed in European Patent Application EP-A-0 731 600. In this prior-art method, one of the lower resolution pictures is selected as a reference picture, and the relative motion between the pixels of the reference picture and each one of the other pictures is estimated with sub-pixel accuracy. Using the motion thus estimated, the lower resolution pictures are scaled to the high-resolution domain and combined to form the high-

15   resolution picture. The relative motion is represented in the form of a mapping transform.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide a method of creating still pictures with advantageous effects in terms of performance and practical implementations.

20   To this end, the method in accordance with the invention comprises the steps of subjecting the sequence of pictures to motion-compensated predictive encoding, thereby generating motion vectors representing motion between successive pictures of said sequence; decoding said encoded pictures; and creating the high-resolution picture from said decoded pictures and the motion vectors generated in said encoding step.

25   The creation of a high-resolution picture from a sequence of lower-resolution pictures relies on the availability of sub-pixel motion information. Employing motion-compensated predictive encoding based on motion between successive pictures (instead of motion between each picture and a fixed reference picture) increases the probability that motion vectors with sub-pixel accuracy will be obtained. The performance of

the method is thus considerably improved. The invention also has the advantage that the sequence of motion-compensated predictively encoded lower-resolution pictures is a compressed representation of the high-resolution still picture. Accordingly, the still picture can efficiently be stored and/or transmitted. Because the motion vectors are part of the stored

5   data, the high-resolution still picture can then be obtained without necessitating another motion estimator. A further advantage is that, upon reproduction, the user may select creation of the high-resolution still picture or playback of the original lower-resolution video sequence.

Preferably, the step of encoding the sequence of pictures comprises the

10   use of an MPEG encoder which is arranged to produce an IPPP.. sequence of encoded pictures. Cost-effective MPEG encoders with high compression ratios are readily available.

In an embodiment of the invention, the high-resolution still picture is created by recursively adding a current decoded picture to a previously created picture, said previously created picture being subjected to motion-compensation in accordance with the

15   motion vector which is associated with the current decoded picture. It is thereby achieved that the still picture is gradually built-up in a single picture memory.

The invention can also be used to create a high-resolution still picture from an already available (received or recorded) sequence of motion-compensated predictively encoded lower-resolution pictures, for example, an MPEG bitstream.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows various pictures to illustrate the prior art method of creating a high-resolution picture.

Fig.2 shows a block diagram of a system carrying out the method of

25   creating a high-resolution picture in accordance with the invention.

Figs. 3 and 4 show various pictures to illustrate the operation of the system which is shown in Fig.2.

DESCRIPTION OF EMBODIMENTS

30   Fig. 1 shows various pictures to illustrate the prior art method of creating a high-resolution picture. In this Figure, the pictures A_1, A_2 and A_3 show three successive phases of a moving object. The pictures B_1, B_2 and B_3 denote the corresponding pixel values on a low-resolution grid as generated by a low-resolution image sensor. Throughout this

description, pixels will have a value in the range 0-100, the value 0 not being shown in the various picture diagrams.

In the prior art, amounts of motion are calculated between the pixels of a fixed reference picture and each one of the subsequent pictures. In the example shown in Fig.1, picture B_1 is the reference picture. To simplify the example, it is assumed that all pixels of the object have the same amount of motion, so that a single motion vector is obtained for each subsequent picture. Accordingly, motion vector m_{12} represents the amount of motion between pictures B_1 and B_2. The vector is assumed to have the value $m_{12} = (1, \frac{1}{2})$, denoting a motion by 1 pixel to the right and $\frac{1}{2}$ pixel upwards. Similarly, the motion vector m_{13} indicates the amount of motion between pictures B_1 and B_3. This vector is assumed to have the value $m_{13} = (1\frac{1}{2}, \frac{1}{2})$.

The pictures C_1, C_2 and C_3 are the respective versions of pictures B_1, B_2 and B_3 on the high-resolution grid. They are obtained by up-sampling. In this example, in which the motion estimation is carried out at half-pixel accuracy, the high resolution is twice the low resolution in both the horizontal and the vertical direction. The up-sampling is carried out by repeating each pixel four times.

The pictures D_1, D_2 and D_3 are the pictures obtained by moving back the pictures C_1, C_2 and C_3 through a distance corresponding to their motion vectors. The respective motion vectors m'_{12} and m'_{13} in the high-resolution domain are obtained by multiplying the original motion vectors m_{12} and m_{13} in the low-resolution domain by the resolution enhancement factor -2. Thus, picture C_2 is shifted 2 pixels to the left and 1 pixel downwards, and picture C_3 is shifted 3 pixels to the left and 1 pixel downwards.

Finally, picture E is the result of adding together the pictures D_1, D_2 and D_3, and dividing the sum by 3 (the number of pictures). As can be seen, picture E starts to reveal high-resolution details of the original object. The more further pictures are processed in this manner, the better the resemblance.

Fig.2 shows a block diagram of a system carrying out the method in accordance with the invention. The system comprises an image sensor 1, a motion-compensated prediction encoder 2, a storage medium (or transmission channel) 3, a motion-compensated prediction decoder 4 and a processing circuit 5 for creating the high-resolution picture. The image sensor receives images A_i corresponding to the pictures A_1, A_2 and A_3 shown in Fig.1, and generates digitized low-resolution pictures B_i corresponding to the pictures B_1, B_2 and B_3 shown in Fig.1.

The motion-compensated prediction encoder 2 (preferably a standard MPEG encoder such as the Philips integrated circuit SAA7650) encodes and compresses the pictures in accordance with the MPEG2 coding standard. The encoder comprises a subtracter 21, an adder 22, a frame memory 23, a motion estimator 24 and a motion compensator 25. Elements which are not essential for understanding the invention, such as a discrete cosine transformer, a quantizer and a variable-length encoder have been omitted. The operation of the encoder will briefly be explained with reference to Fig.3. In this Figure, the input images A_1, A_2 and A_3 and their digital counterparts B_1, B_2 and B_3 are the same as in Fig.1.

The first picture B_1 of the sequence is autonomously encoded. In MPEG coding, such a picture is usually referred to as an I-picture. In Fig.3, picture D_1 shows the pixel values of the autonomously encoded picture. The picture is applied to the encoder's output and also stored in the frame memory 23.

The further pictures B_2 and B_3 are predictively encoded. In MPEG coding, they are usually referred to as P-pictures. To encode these pictures, the motion estimator 24 calculates the amount of motion between the current picture B_i and the stored previously encoded picture B_{i-1}. Usually, said motion estimation is carried out on the basis of blocks of 16*16 pixels. Using the calculated motion vector, the motion compensator 25 generates a prediction picture C_i which is subtracted from the picture B_i to be encoded so as to form a difference output picture D_i. The prediction image C_i and the encoded difference D_i are added by adder 22 and stored in the frame memory 23.

Picture C_2 in Fig.3 is the motion-compensated prediction picture for encoding the picture B_2. As in the prior art, the relevant motion vector m_{12} is assumed to have the value (1,½). Picture B_2 is thus encoded in the form of a difference picture which is shown as D_2 in Fig.3.

Similarly, picture C_3 is the motion-compensated prediction picture for encoding the picture B_3. Note that the motion vector m_{23} is representative of the amount of motion between pictures B_2 and B_3. This is in contrast to the prior art in which all motion vectors are calculated with respect to the same reference picture B_1. In the present example, motion vector m_{23} has the value (½,0). Picture B_3 is now encoded in the form of difference picture D_3.

With reference to Fig.2 again, the encoded pictures D_i along with the motion vectors m are stored on a storage medium 3 or transmitted through a transmission channel. Subsequently, the original sequence of low-resolution pictures is decoded by the motion-compensated prediction decoder 4. Again, only the most relevant elements of this

(MPEG) decoder are shown, i.e. an adder 41, a frame memory 42 and a motion-compensator 43 which receives the motion vectors m as produced by the encoder.

After reconstructing the original low-resolution pictures, the high-resolution still picture is recursively created by the processing circuit 5. As shown in Fig.2, this processing circuit 5 comprises an up-sampler 51, a multiplier 52, an adder 53, a frame memory 54 and a motion compensator 55.

Fig.4 shows various pictures to illustrate the operation of the processing circuit. The pictures B_1, B_2 and B_3 are the decoded low-resolution pictures supplied by the prediction decoder 4. Apart from artefacts due with the imperfectness of the compression by the encoder, they correspond with the pictures B_1, B_2 and B_3 shown in Figs. 1 and 3. Pictures E_1, E_2 and E_3 are their versions in the high-resolution domain. They are supplied by up-sampler 51 by pixel repetition.

In a first iteration step, the processing circuit 5 outputs the first high-resolution picture G_1 and feeds it into the frame memory 54. Because the first picture is an I-picture, the output picture G_1 is the same as input picture E_1.

In a second iteration step, the next high-resolution picture E_2 and a motion-compensated previous picture F_2 are added by adder 53. The motion-compensated picture F_2 is obtained by shifting the stored picture G_1 two pixels to the right and one pixel upwards in accordance with motion vector $m'_{12}=(2,1)$ which is twice the original motion vector m_{12}. Picture G_2 is the result of this iteration step. The pixel values shown have been normalized, i.e. divided by 2 which is the number of pictures processed thus far. As can be seen, high-resolution details start to appear in the vertical direction. Details do not yet appear in the horizontal direction because the original motion vector m_{12} has a sub-pixel component in the vertical direction only. The output picture G_2 (without the normalization factor being applied) is stored in frame memory 54.

In a third iteration step, the next high-resolution picture E_3 and a motion-compensated previous picture F_3 are added. The latter is obtained by shifting the stored picture G_2 one pixel to the right in accordance with motion vector $m'_{23}=(1,0)$. Picture G_3 is the result of this iteration step. The pixel values shown are obtained after division by 3, which is the number of pictures processed thus far. As can be seen, high-resolution details now start to appear also in the horizontal direction, because the original motion vector m_{23} has a sub-pixel component in this direction.

The above described steps are repeated for each further picture in the sequence of decoded pictures. The more subsequent P-pictures are processed in this manner, the better the output picture will resemble the original object.

As will be appreciated, the invention offers the particular advantage that

5   the motion vectors obtained in the encoding phase are also used in the still-picture creation phase. It is not necessary to have another motion estimator. Neither is a memory for each picture required. Furthermore, the motion vectors refer to the immediately preceding picture rather than to a fixed reference picture. Because motion between successive pictures is relatively small, the probability of obtaining motion vectors with half-pixel accuracy (which

10   is essential for resolution doubling) is therefore considerably greater than in the prior art.

The invention also allows still pictures to be transmitted or stored as a sequence of compressed low-resolution pictures, which requires a moderate transmission or storage capacity. Widely available standard components (MPEG encoders and decoders) can be used, and the sequence of low-resolution pictures can optionally be reproduced in the

15   form of motion video.

In summary, a method and arrangement is disclosed for creating a high-resolution still picture. A sequence of lower-resolution pictures is subjected to motion-compensated predictive encoding, preferably by an MPEG encoder producing an IPPP.. sequence of encoded pictures. The relatively small differences between successive pictures,

20   which are due to motion of the image sensor or motion in the scene, become manifest in motion vectors with sub-pixel accuracy. The high-resolution picture is then created from the decoded pictures and the motion vectors generated by the encoder.

The invention is particularly applicable in electronic still picture cameras with a storage medium. The MPEG encoder takes care of data compression, and the decoder

25   also allows playback of the original moving video sequence.

CLAIMS

1.   A method of creating a high-resolution still picture, comprising the steps of:

receiving a sequence of lower-resolution pictures;

estimating motion in said sequence of lower-resolution pictures with sub-pixel

5   accuracy; and

creating the high-resolution still picture from said sequence of lower-resolution pictures and said estimated motion;

characterized in that the method comprises the steps of:

subjecting the sequence of pictures to motion-compensated predictive encoding,

10   thereby generating motion vectors representing motion between successive pictures of said sequence;

decoding said encoded pictures; and

creating the high-resolution picture from said decoded pictures and the motion vectors generated in said encoding step.

15   2.   The method as claimed in claim 1, wherein the creating step includes recursively adding, in the high-resolution domain, a current decoded picture to a previously created picture, said previously created picture being subjected to motion-compensation in accordance with the motion vector which is associated with the current decoded picture.

3.   The method as claimed in claim 1, further comprising the step of storing

20   the encoded pictures on a storage medium.

4.   The method as claimed in claim 1, wherein the step of encoding the sequence of pictures comprises the use of an MPEG encoder which is arranged to produce an IPPP.. sequence of encoded pictures.

5.   A method of creating a high-resolution still picture from a sequence of

25   lower-resolution pictures received in the form of motion-compensated predictively encoded pictures and motion vectors representing motion between successive pictures of said sequence, comprising the steps of:

decoding said encoded pictures; and

creating the high-resolution picture from said decoded pictures and the received motion vectors.

6.   The method as claimed in claim 5, wherein the creating step includes recursively adding, in the high-resolution domain, a current decoded picture to a previously created picture, said previously created picture being subjected to motion compensation in accordance with the motion vector which is associated with the current decoded picture.

7.   The method as claimed in claim 5, wherein the sequence of motion-compensated predictively encoded pictures and motion vectors is received in the form of an MPEG video bitstream comprising an IPPP.. sequence of encoded pictures.

8.   An arrangement for creating a high-resolution still picture, comprising:

means (1) for receiving a sequence of lower-resolution pictures;

means for estimating motion in said sequence of lower-resolution pictures with sub-pixel accuracy; and

means (5) for creating the high-resolution still picture from said sequence of lower-resolution pictures and said motion vectors;

characterized in that the arrangement further comprises:

an encoder (2) for subjecting the sequence of pictures to motion-compensated predictive encoding, including a motion estimator (24) for generating motion vectors representing motion between successive pictures of said sequence;

a decoder (4) for decoding said encoded pictures;

the creating means (5) being arranged to create the high-resolution picture from said decoded pictures and the motion vectors generated by the encoder (2).

9.   The arrangement as claimed in claim 8, wherein the creating means include means (53,54) for recursively adding, in the high-resolution domain, a current decoded picture to a previously created picture, said previously created picture being subjected to motion compensation (55) in accordance with the motion vector which is associated with the current decoded picture.

10.   The arrangement as claimed in claim 8, further comprising a storage medium (3) for storing the encoded pictures.

11.   The arrangement as claimed in claim 8, wherein the encoder (2) is an MPEG encoder which is arranged to produce an IPPP.. sequence of encoded pictures.

12.   An arrangement for creating a high-resolution still picture, comprising:

means for receiving a sequence of lower-resolution pictures in the form of motion-compensated predictively encoded pictures and motion vectors representing motion between successive pictures of said sequence;

a decoder (4) for decoding said encoded pictures; and

5   means (5) for creating the high-resolution picture from said decoded pictures and the received motion vectors.

13.   An image recording and reproducing apparatus, comprising an arrangement as claimed in claim 10, and further comprising an image sensor (1) for obtaining the lower-resolution pictures.
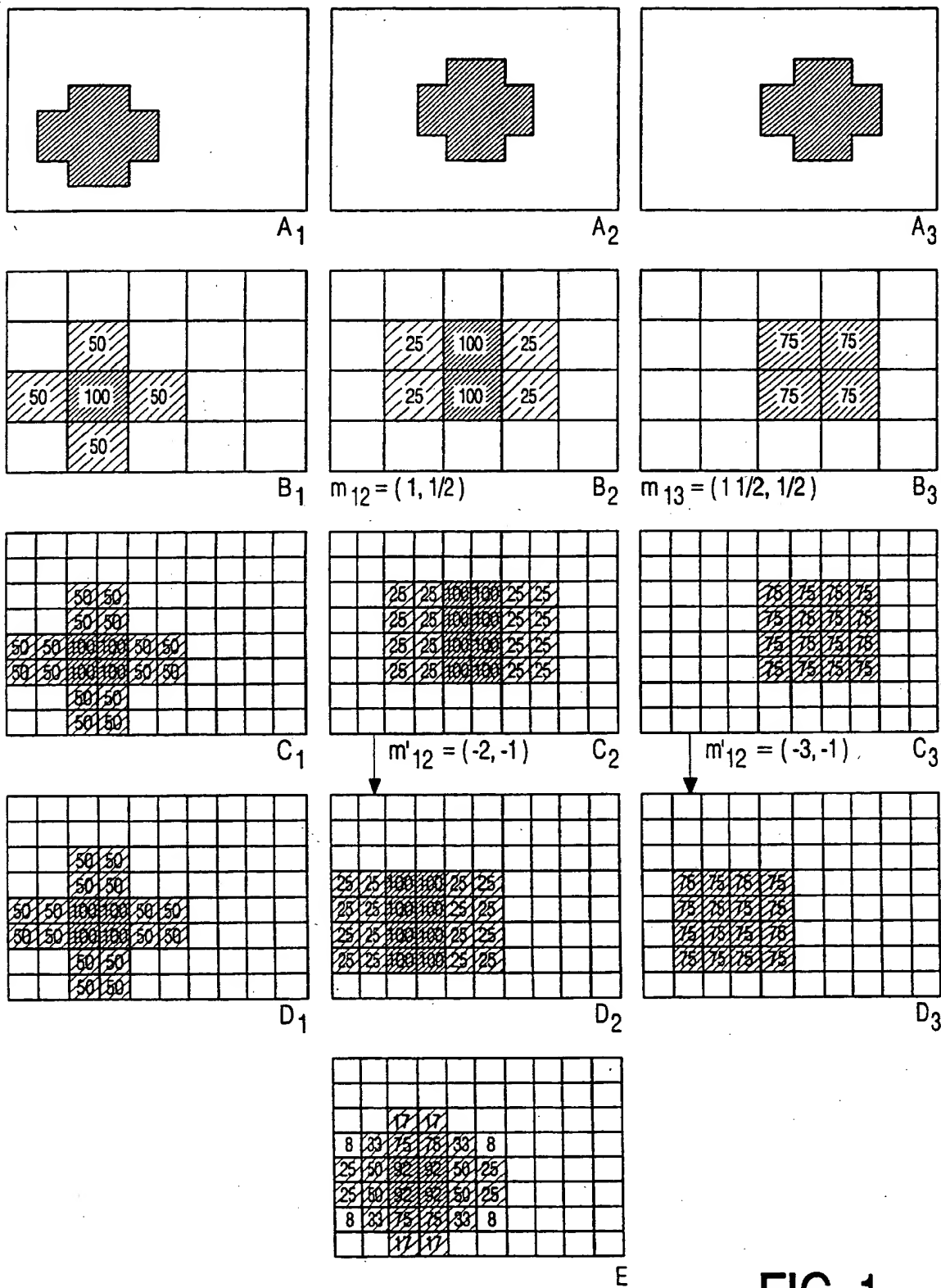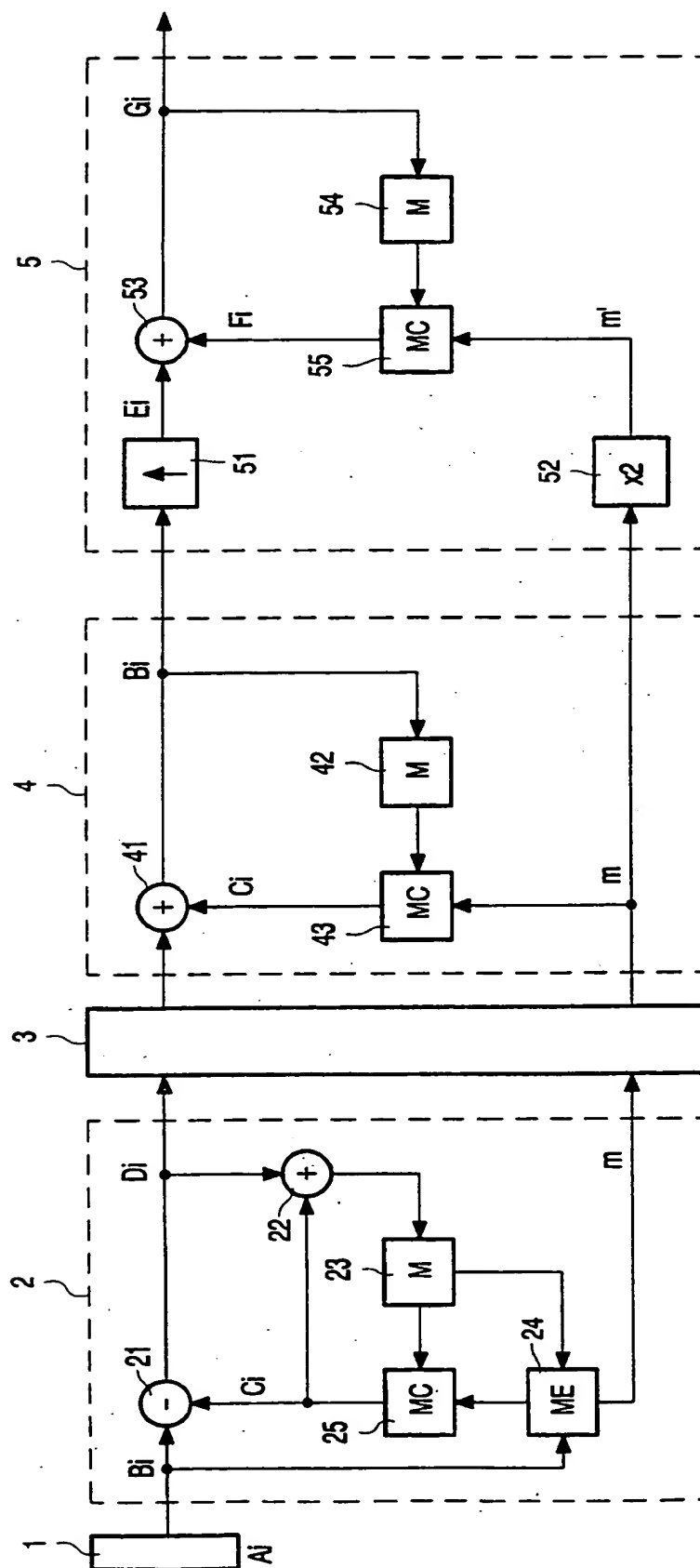
FIG. 1

FIG. 2

FIG. 3

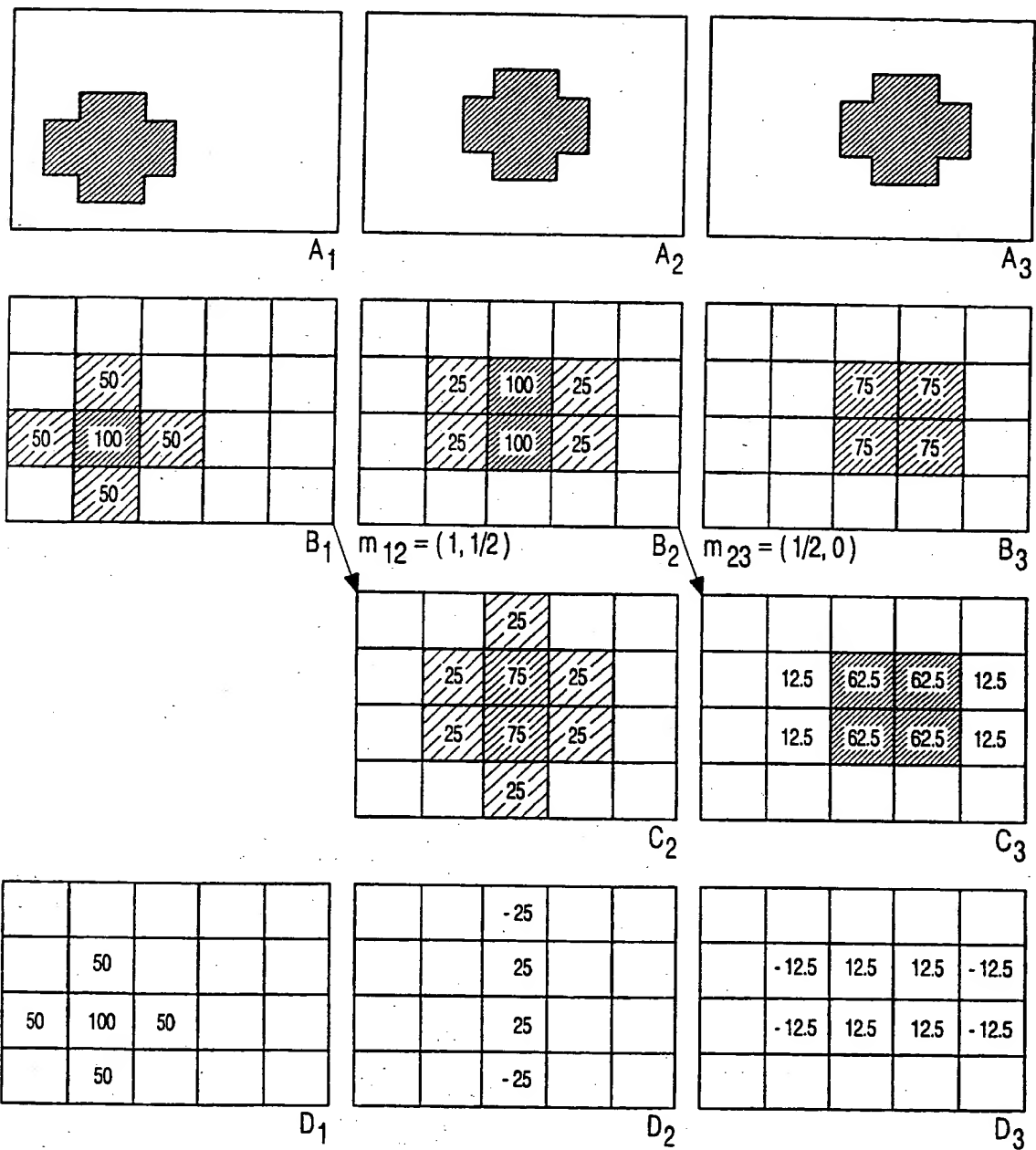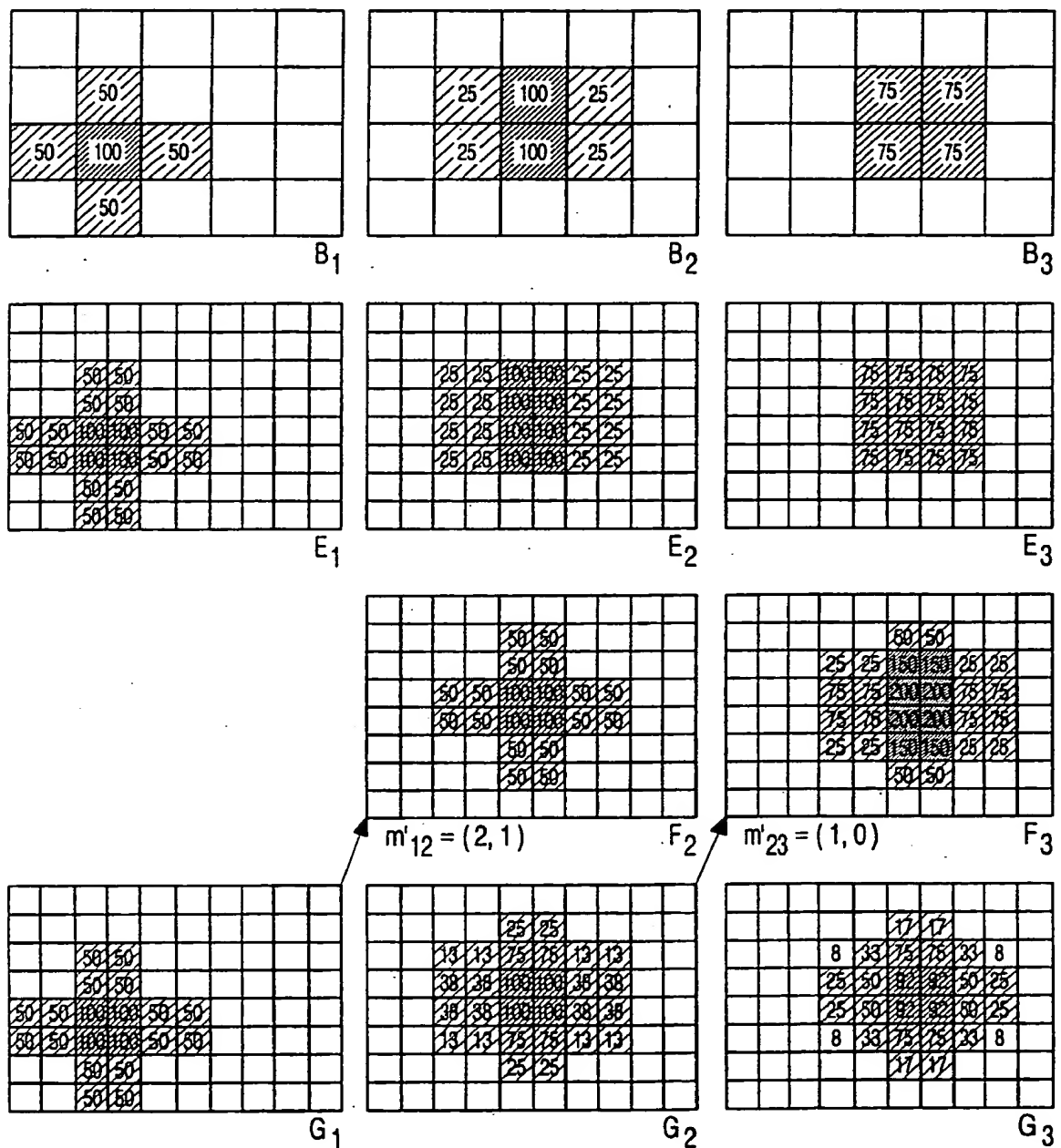FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 98/01966

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G06T 5/50, H04N 5/14, H04N 7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G06T, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5696848 A (A.J. PATTI ET AL.), 9 December 1997 (09.12.97), abstract	1-13
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A	US 5657402 A (W.R: BENDER ET AL.), 12 August 1997 (12.08.97), column 9, line 38 - line 45	1-13
	--	
A	US 5341174 A (K. XUE ET AL.), 23 August 1994 (23.08.94), abstract	1-13
	--	

X	Further documents are listed in the continuation of Box C.	X	See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 May 1999	2 7 -05- 1999

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB 98/01966

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP7015654 A (RICOH KK) 1995-01-17 (abstract) World Patents Index (online). London, U.K.: Derwent Publications, Ltd. (retrieved on 1999-05-20). Retrieved from: EPO WPI Database. DW 9512, Accession No. 95-087518; & JP 7015654 (RICOH CO LTD) 1995-05-31 (abstract). (online)(retrieved on 1999-05-20). Retrieved from: EPO PAJ Database -- --------	1-13

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 5696848 A	09/12/97	EP	0731600 A	11/09/96
		JP	8263639 A	11/10/96
US 5657402 A	12/08/97	JP	8503088 T	02/04/96
		WO	9410653 A	11/05/94
		JP	5304675 A	16/11/93
US 5341174 A	23/08/94	NONE		